Revisiting Urban Expansion in the Continental United States

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Abstract

Nearly 0.4% of all land within the contiguous United States (US), an area larger than the state of Maryland, was developed between 2001 and 2016. Though significant, the scale of expansion was much smaller than previously predicted, representing an emergent non-linear pattern. This paper revisits the quantitative study of urban expansion (UE) using the National Land Cover Database, comparing UE against population growth to calculate Expansion per Capita (EPC) for 379 metro areas. EPC is examined longitudinally by geographic region and metro size. Metros across the US, big and small, are using considerably less land to accommodate population growth. This pattern accelerated, with a cumulative 62% reduction in metro EPC by the ’11 to ’16 period. This corresponds to a 1 million hectare reduction in expansion.

Highlights

- Urban expansion in the US mainland has declined by over 50% since 2001
- 96% of the reduction occurs in US metro regions
- 87% of metro population growth was in those with declining expansion per capita
- The reduction trend is durable across metro size and geographic region

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1. Introduction

The conversion from agricultural or natural lands to developed landscapes, or urban expansion (UE), is one of the central environmental threats posed by urban growth. Global UE is substantial with major implications for natural resources, the climate, and biodiversity (Seto, Güneralp, & Hutyra, 2012; d'Amour et al., 2017; Huang, McDonald, & Seto, 2018). This ominous pattern is exacerbated by the increasing global tendency for development to be declining in density (Seto, Sánchez-Rodríguez, & Fragkias, 2010; Angel, Parent, Civco, Blei, & Potere, 2011; Wheeler, 2015). However, a non-linear shift has occurred in the continental United States ("US" hereafter), with UE accelerating from the 1980s through 1997 and then rapidly declining through 2016, see Figure 1.

UE researchers rely on a variety of data sources and models to analyze and predict land change, with significant variation between approaches (Sohl, Wimberly, Radeloff, Theobald, & Sleeter, 2016). One central challenge is the availability of consistent and conformable time-series data (Sohl et al., 2016; Wentz et al., 2018). Two datasets that overcome this barrier for the US are the National Resource Inventory (NRI) and the National Land Cover Database (NLCD). The NRI began collecting data in 1982 and applies stratified area sampling to create aggregate estimates of land cover by US state (US Department of Agriculture, 2018). The NLCD applies complex digital change detection methods (Yang et al., 2018) to Landsat imagery to comprehensively classify land cover at a 30-m resolution, with longitudinal data beginning in 2001 (Homer et al., 2020). Despite different methodologies, both show substantial declines in UE.

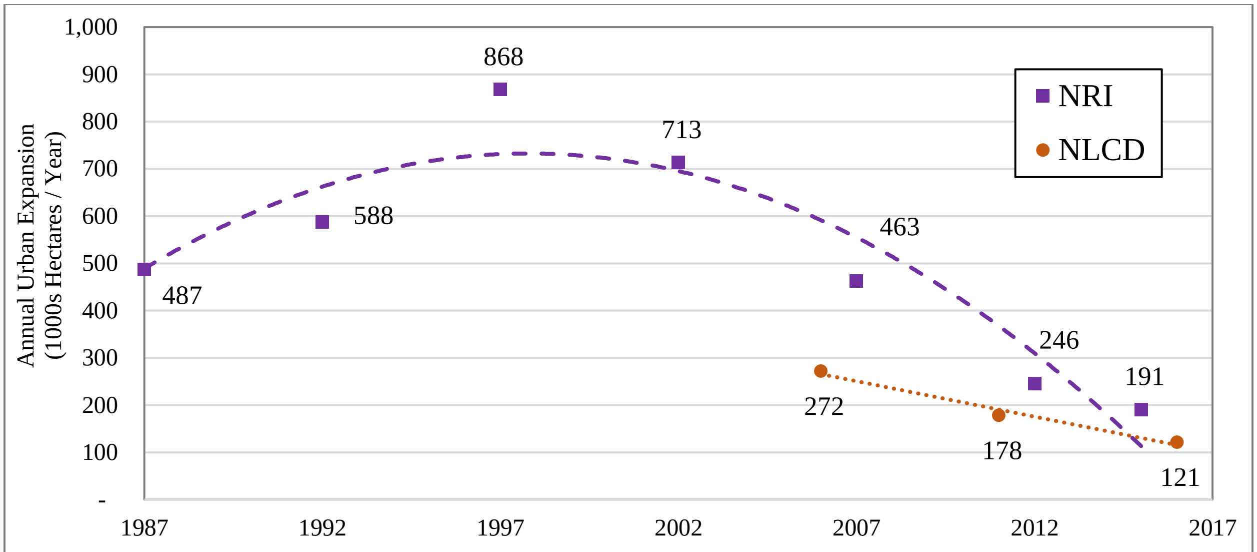

Figure 1: Annual Urban Expansion Rates for the NRI and NLCD. The Annual UE rate is calculated by 1) calculating UE between two epochs, 2) calculating the number of years between two epochs, and 3) dividing UE by those years. Each value is graphed at the end of the interval.

Although national aggregate UE trends are informative, there is significant regional variation across the US. Metropolitan regions ("metros" hereafter), an important scale for the study of urban systems (Bixler et al., 2019), are especially pertinent for examination of UE since 96% of the reduction has occurred therein (see Appendix A). Given this pattern, this research leverages exploratory analysis of the NLCD to investigate the UE reduction through longitudinal examination of regional and metro trends. In doing so, it provides important insight into the dynamics of urban growth, which are more dynamic and less predictable than past studies presumed.

1.1 Past Studies of Urban Expansion

Fulton, Pendall, Nguyen, and Harrison (2001) provide a baseline of UE in the US. Analyzing NRI data from 1982 to 1997 against population growth, the authors found: metros in the Western US are both denser and consume less land than those elsewhere; the Southern US is growing quickly in terms of population and UE; and the Northeast and Midwest are expanding rapidly given relatively small population growth. Much of the literature after Fulton et al. (2001)

focuses on modeling future development instead of examining recent trends. Sohl et al. (2016) provide a helpful review, finding significant variation among temporal, spatial, and thematic characteristics.

In theory, the NRI and NLCD should have led to improved modelling; however, the emergence of NLCD just after the UE peak in the NRI may have slowed this process. Models that use NRI data often stop at 1997 (Alig, Kline, & Lichtenstein, 2004; Wear, 2011; Lawler et al., 2014), which understandably led to overestimation. Even the lowest of these forecasts (see Table 1) were well above the annual UE rate of 316 hectares (1000s per year) recorded by the NRI from 2002 to 2015, or the 190 hectares (1000s per year) in the NLCD from 2001 to 2016.

Source	**Annual UE Rate (1000s Hectares / Year)**	**Forecast Range**
Alig et al. (2004)	484 – 1,893 (1,109 most likely)	1997 – 2025
Wear (2011)	405 – 567	1997 – 2020
Lawler et al. (2014)	590	2001 – 2051

Table 1: Forecasts of Urban Expansion for Continental United States

NLCD-based approaches are still emerging as the 2001 version only became available in 2007, making longitudinal study of NLCD a relatively new approach. Some studies rely on the older 1992 NLCD (e.g. Elvidge et al., 2004; Sohl et al., 2014); however, it is not part of the longitudinal database and, due to difference in methodology, the use of the 1992 NLCD for longitudinal analysis is strongly discouraged (Multi-Resolution Land Characteristics Consortium, personal communication, October 21, 2019). Two national studies that use the more recent NLCD but do not model future change both found that development density had slightly increased between 2001 and 2011 (Ewing & Hamidi, 2016; Landis, 2017). Neither attribute much significance to the pattern. Focusing on UE instead of density demonstrates the magnitude of change, with 50% less UE taking place between 2011 to 2016 than from 2001 to 2006 (Homer et al., 2020).

2. Methods

There are several approaches to measuring UE (e.g. Angel et al., 2011; Jiao, 2015; Kuang, Liu, Dong, Chi, & Zhang, 2016), many of which are based on manual processing of remote sensing data. This paper, however, relies on the 2016 version of NLCD (released May 2019) to calculate total developed land for 2001, 2006, 2011, and 2016. Total developed lands are equal to the sum of the four different developed land cover classes (21 – Developed, Open Space; 22 – Developed, Low Intensity; 23 – Developed, Medium Intensity; and 24 – Developed, High Intensity). UE is calculated as the difference in developed land between two time periods.

In addition to the NLCD data, population counts for 2001, 2006, 2011, and 2016 were acquired from the US Census Annual Estimates of the Resident Population. Given the direct and positive relationship to UE (Alig and Healy, 1987; Alig et al., 2004), population data provides essential demographic context for the study of UE. To account for this relationship, this research relies on an Expansion per Capita (EPC) metric calculated by dividing UE by population growth. Given the four years of data, EPC has been calculated across three intervals: 2001 to 2006, 2006 to 2011, and 2011 to 2016.

Regional analysis is conducted in alignment with the groupings used by Alig et al. (2004). This paper uses the 2017 Metropolitan Statistical Area delineation to group counties into 379 metros, which are categorized into three population groups: less than 250k, between 250k and 750k, and greater than 750k.

3. Results

Focusing exclusively on metros shows an even greater reduction in UE than was identified by Homer et al. (2020) (Figure 2). Metro EPC drops 62% from 97 hectares per 1000 new persons to 37 hectares per 1000 new persons. Shifts in distribution of population growth to more land-efficient regions could potentially drive the national trend. For example, if population growth shifted towards larger cities, this might itself lower national EPC figures because larger cities tend to consume less land per capita. However, the EPC reduction trend is durable across region and metro size (Figure 3).

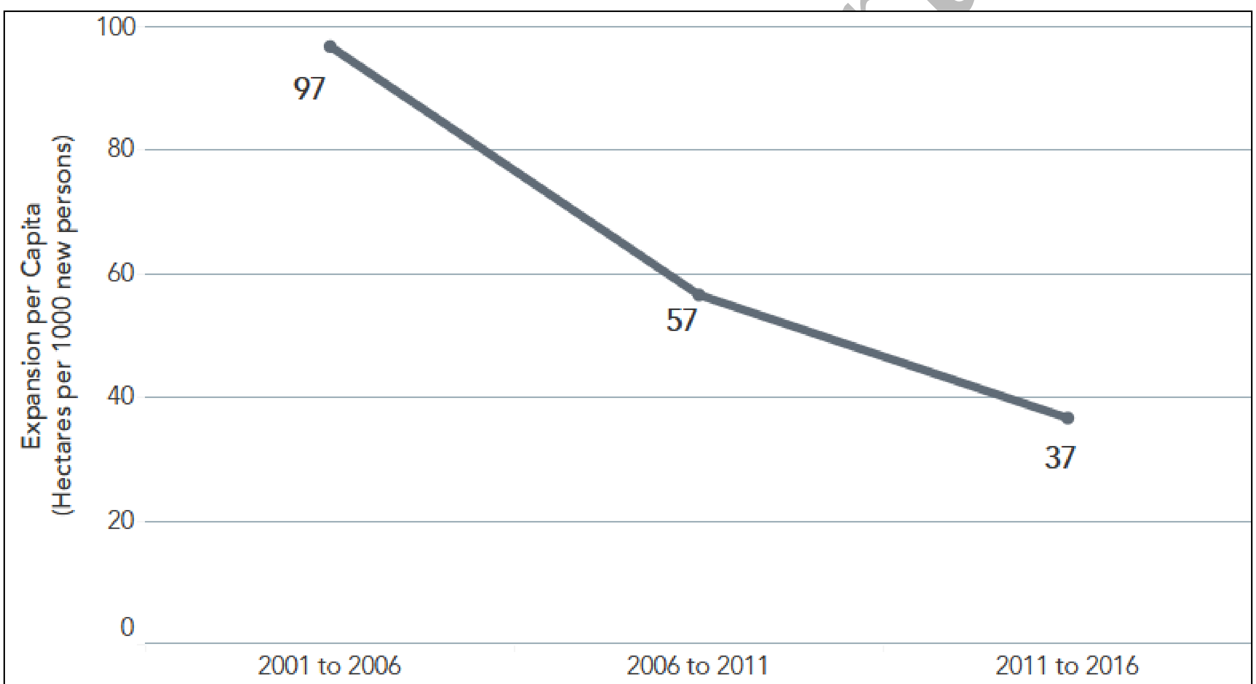

Figure 2: Expansion per Capita (EPC) from 2001 to 2016, by NLCD interval

Regional definitions: California; Great Plains – MT, ND, NE, SD, WY; Northeast – CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT; Northern Midwest – IA, IL, IN, MI, MN, MO, OH, WI; Pacific Northwest – ID, OR, WA; South – AL, FL, GA, KY, MS, NC, SC, TN, VA, WV; Southern Midwest – AR, KS, LA, OK, TX; Southwest – AZ, CO, NM, NV, UT.

Figure 3: EPC from 2001 to 2016, by NLCD interval, region, and metro size. Line width represents population growth from '01 to '16.

Of the 24 region-metro size intersections, only four (small metros in California, Southern Midwest, Southwest and medium metros in Northeast) increased in EPC over the study period. These four have narrow line widths, indicating only a small portion of overall population growth located therein. Overall, 69% of all metros experienced EPC reduction (66% of small, 69% of medium, 81% of large); however, population growth is heavily concentrated in metros that saw a reduction, with 32 million of the approximate 37 million (87%) in metro population growth from ’01 to ’16 occurring in those with declining EPC.

4. Discussion

4.1 Revisiting Patterns of Urban Expansion

Before examining this new trend, it is important to first identify consistency with past literature. Regional patterns identified in Fulton et al. (2001) and Alig et al. (2004) mostly hold true. The Western US still consumes less land per capita, often substantially less. The Midwest, Great Plains, and much of the Northeast continues to be highly consumptive of land. The one regional exception would be the South, where medium and large metros experienced substantial reductions in EPC, though this trend may be less durable, as will be discussed in Section 4.2.

The greatest divergence from past UE studies is clearly the rapid reduction in UE. Ewing and Hamidi (2016) and Landis (2017) found a small increase in density from 2001 to 2011, but the EPC metric and inclusion of 2016 data better capture the trend. Like previous work, this research finds a small increase in density (by .5 persons per hectare), but a 62% reduction in metro EPC points to a more significant trend, one which saw a cumulative UE reduction of 1 million hectares. Metro-wide development densities include all existing developed lands as well as recent expansion. Conversely, EPC isolates UE, preventing the much larger existing landscape from quantitatively overwhelming it and thus obscuring rapidly changing development patterns.

It is also important to differentiate the study of UE from a broader discourse on sprawl. Fulton et al. (2001) foreground sprawl in their study, but the sprawl literature has generally evolved to include other dimensions of development such as land-use mix, activity centering, and street accessibility (Ewing & Hamidi, 2016) and/or density gradients (Landis, 2017). In addition to these physical and functional dimensions, there are other social, process, and analytical dimensions to be considered (Forsyth, 2012). Therefore, the reduction of UE identified in this research does not necessarily imply a reduction in sprawl.

4.2 Possible Drivers of Decelerating Expansion

One goal of exploratory analysis is the generation of new research questions. The most obvious question that has emerged is: “what is driving the reduction of expansion per capita?” While not the focus of the empirical work presented in the Results section, there are several potential drivers worth discussing.

One possibility is the recent shift in locational preference towards denser, central urban areas. Some see this trend as demographic in nature, with the retirement of baby boomers and emergence of millennials as large sources of demand for more compact forms of development (Nelson, 2013; Myers, 2016). This suggests that demographic data used in previous studies – population growth and household size (Alig et al., 2004) or immigrant population (Fulton et al., 2001) – missed a key differentiating variable, one that is testable now and, given the millennial cohort peaked in 2015 and should begin to reverse by 2020 (Myers, 2016), could lead to an increased rate of expansion in the near term.

It is important to note that residential development only constitutes a portion of overall development with office, retail, industrial, and transportation (including roads) each requiring significant land area. The office sector has seen significant densification with the 94 largest metros experiencing a 30% increase in job density from 2004 to 2015 (Shearer, Vey, & Kim, 2019). The increase in job density exceeds job growth overall, perhaps demonstrating a locational preference in alignment with the residential sector; however, significant variation across metros suggests the pattern is less geographically durable than the EPC reduction trend.

The South experienced mostly decreasing levels of job density, despite substantial decreases in EPC. New York and Chicago are both noteworthy as they account for much of the national increase in job density, yet they have relatively high EPC. Thus, more concentrated, often vertical office development appears not to be driving the EPC reduction trend. Instead, such office density might, possibly through increasing the value of centrally located land, lead to increased rates of expansion.

Another trend that could affect the use of land by the office sector is the rapid increase in remote working (or working from home). Nearly 2.4 million more people worked from home in 2014 than in 2000, a 13% increase that, like the EPC trend, is consistently positive across the US (Kane & Tomer, 2015). Despite a robust trend, it is unclear to what extent increases in remote work translate to reduced EPC.

As for retail and industrial development, both have seen significant conversion to residential and office uses, representing one possible source of EPC reduction. The success of e-commerce and the increased outsourcing of industrial labor both speak to the relevance of larger societal shifts, but also limit to the overall impacts of the EPC trend. If reduced industrial expansion in the US is offset by land-intense development elsewhere, such as the 5-fold increase in industrial land in China (Kuang et al., 2016), the environmental gains need to be understood as local but not global.

There are several other possible factors that might have affected EPC. Exurban development has become more pronounced across the US (Berube, Singer, Wilson, & Frey, 2006). This could translate into metro-level EPC reduction because the development might have occurred outside metro areas, or occurred in such a low density that the structures themselves may have been missed by the NLCD (Irwin, Cho, & Bockstael, 2007). It is also possible that small shifts in land development, such as reduced lot size, parking requirements, or road configuration, might also translate into reduced overall EPC, though systematic longitudinal study of such factors would be challenging. In particular, land used for parking varies widely and sometimes constitutes large portions of urban land (Scharnhorst, 2018). What is clear is that growth in metros with dense, vertical urban cores like New York or Chicago does not imply less EPC. Instead, other structural shifts in demographics, economics, or land development must explain the reduction trend.

One obvious factor thus far omitted is the Great Recession, which occurs in the middle of the study period. The EPC reduction trend begins in 1997 and remains robust ever since. Therefore, the recession may have accelerated the EPC reduction, particularly for those regions where development markets were hardest hit, but it is unlikely to be a driver of the broader phenomenon. However, it could possibly explain the rapid decline of EPC in the South, which has traditionally been consumptive of land (Fulton et al., 2001; Alig et al., 2004) but was one of several regions strongly impacted by the recession (Martin, 2011). Whether EPC will rise again or if the US has seen “peak expansion” remains to be seen.

5. Conclusion

This research contributes to an improved understanding of urban growth in the US, finding significant reduction in the rate of urban expansion using the EPC metric that, unlike measures of density, isolates changing development patterns. The reduction trend has been examined longitudinally by metro size and geographic region, finding a robust trend across both variables. The deceleration of UE is significant, accounting for a cumulative reduction of 1 million hectares, though the drivers and detailed manifestations of this trend remain an area for future research.

Despite the exploratory nature of this work, it clearly identifies a non-linear shift in UE in the US. This represents an emergent phenomenon for those who study urban growth since the US (and global) trend has been the inverse, that of increasingly consumptive land patterns (Seto, Sánchez-Rodríguez, & Fragkias, 2010; Angel, Parent, Civco, Blei, & Potere, 2011; Wheeler, 2015). It is unclear if reduced land consumption will persist in the US or if it will spread to other countries. If it indeed represents a more durable pattern, this work signals an important area of future research for urban growth scholars. Identifying the drivers of the reduction trend would aid planners and policy makers in better predicting and managing urban growth that threatens to consume vast quantities of valuable land (Seto et al., 2012; d'Amour et al., 2017; Huang et al., 2018). That such a significant trend has gone mostly unnoticed is itself an important lesson for urban planning research and practice. In a rapidly changing world, it is essential to continually re-evaluate assumptions about urban growth.

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